Modelling of ELM mitigation at JET

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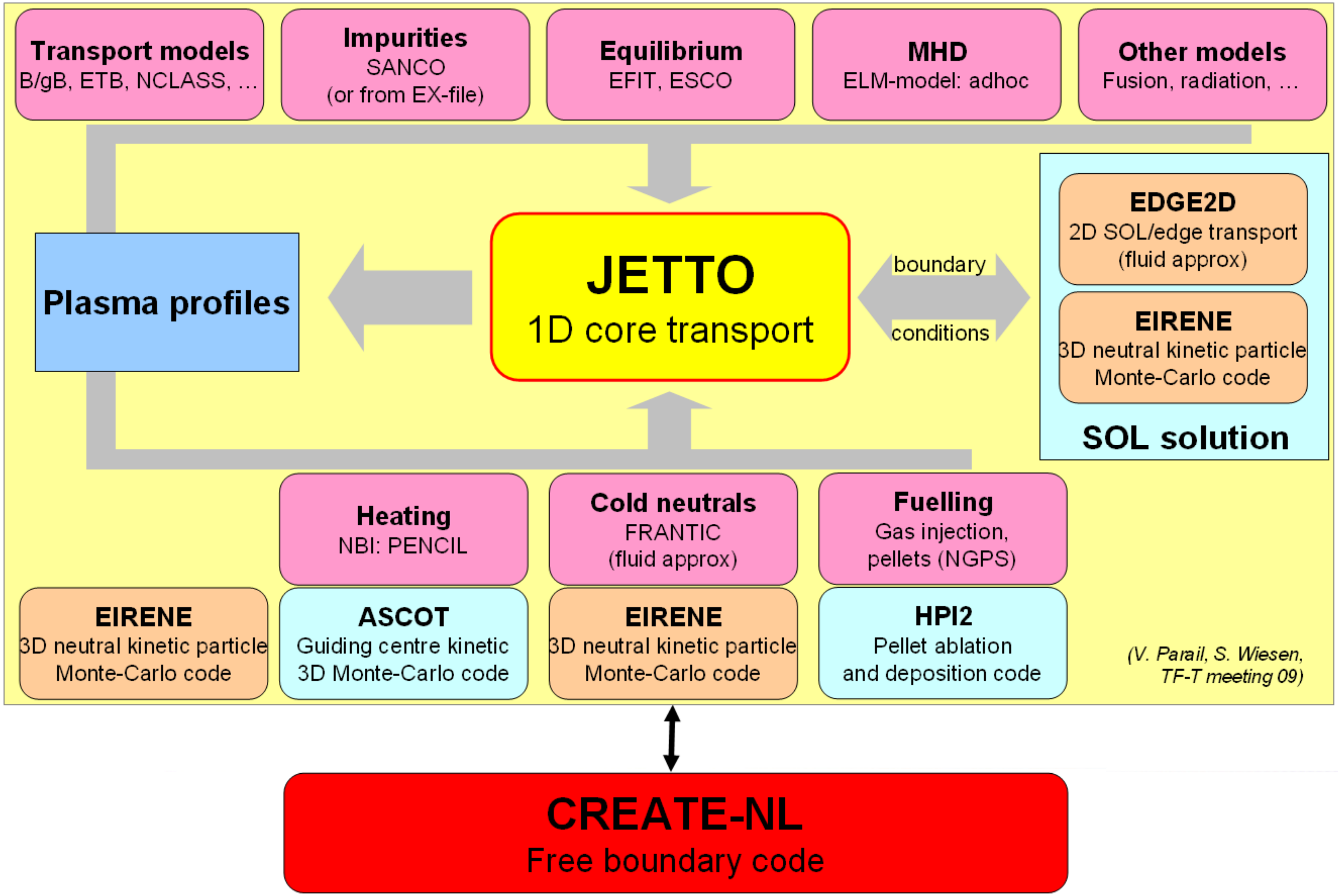
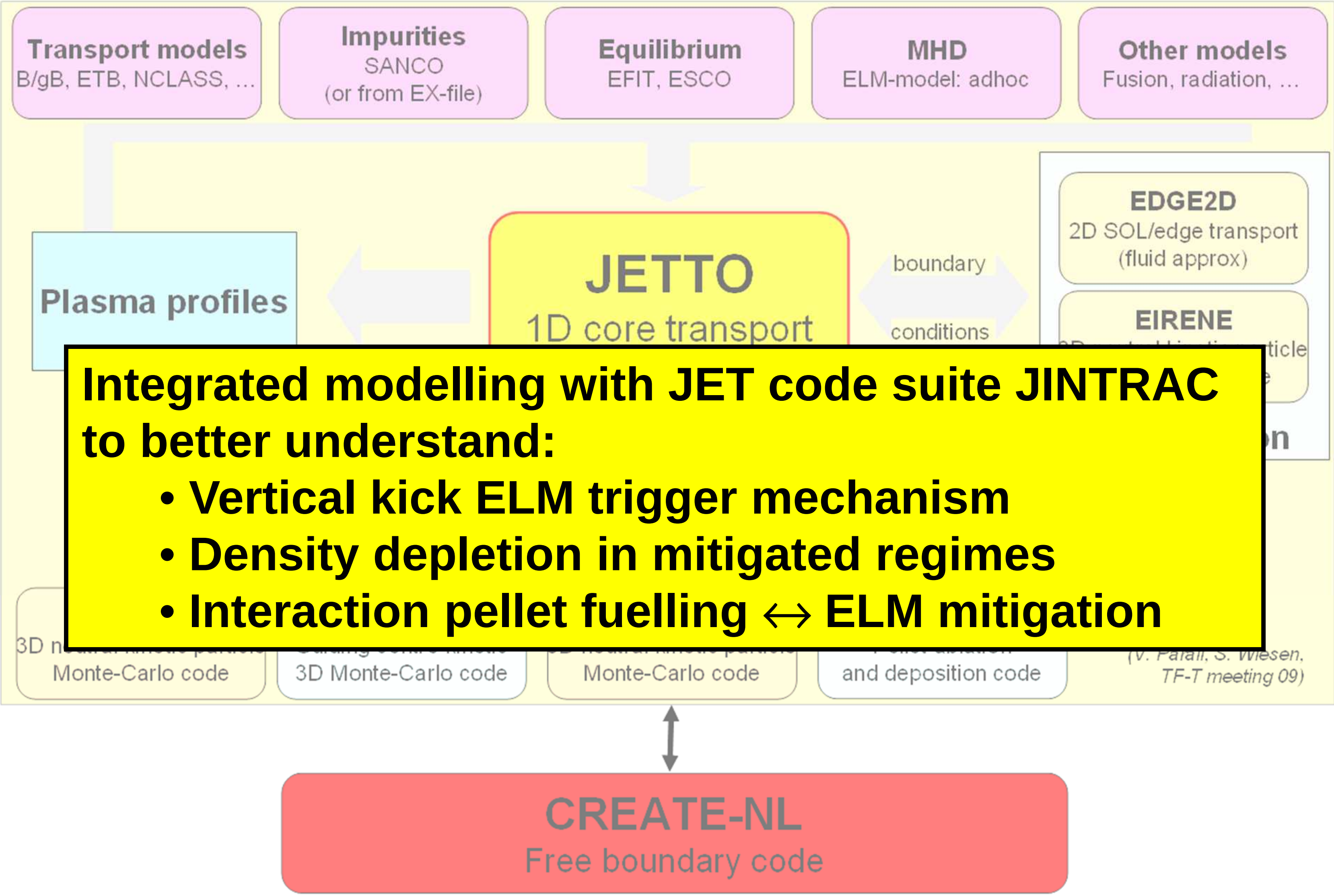
25th SPPT - Prague, 18th-21st June 2012

JINTRAC code suite:



JINTRAC code suite:



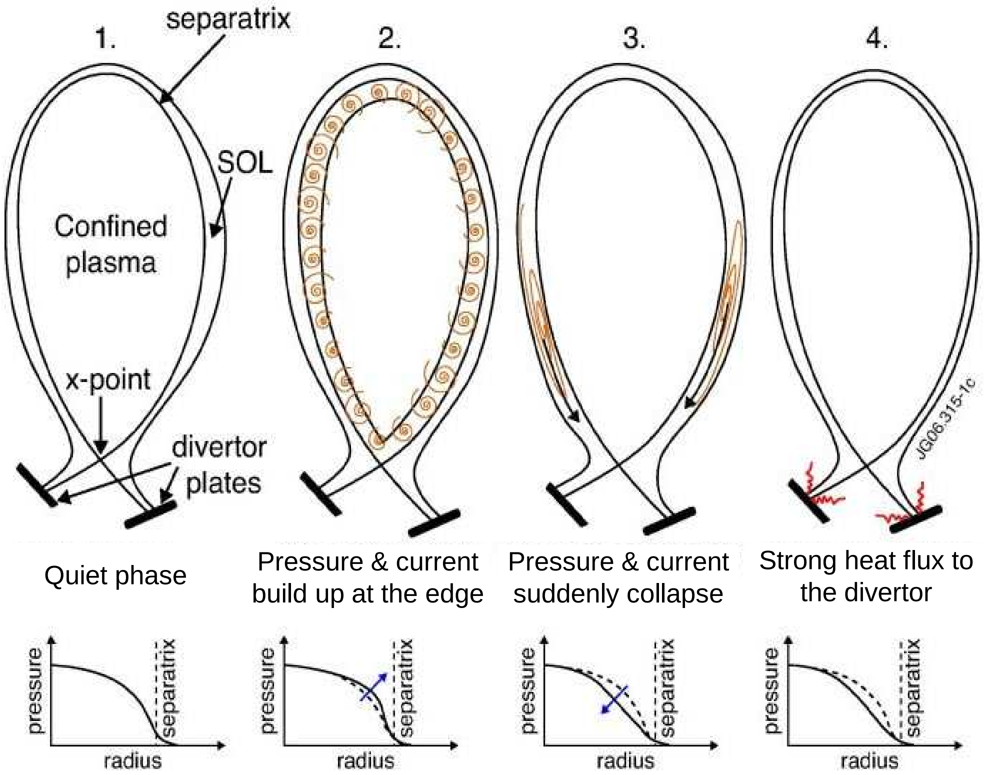
Integrated modelling with JET code suite JINTRAC to better understand:

- **Vertical kick ELM trigger mechanism**
- **Density depletion in mitigated regimes**
- **Interaction pellet fuelling ↔ ELM mitigation**

ELM mitigation:

Edge Localised Modes (ELMs) are repetitive bursts of the edge plasma:

- **Large ELMs in ITER would accelerate erosion of plasma facing components!**
- **Tolerable energy density for ITER divertor target plates: < 0.5 MJm^{-2}**
- **This requires ELM size reduction by a factor ≈ 20!**

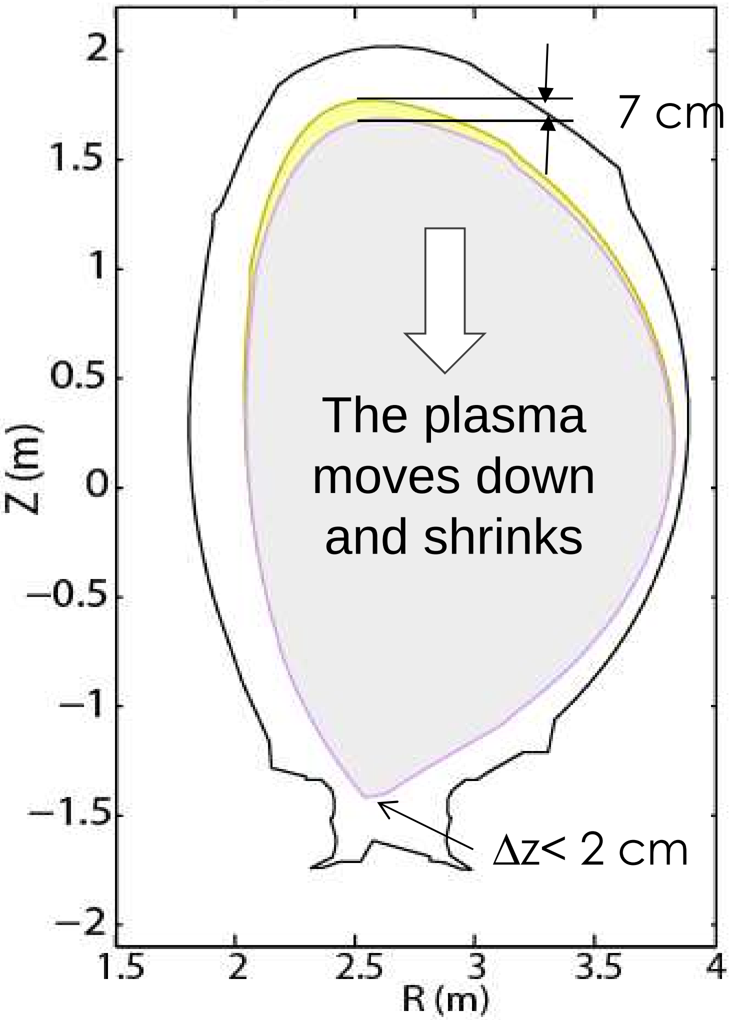


Various methods for ELM size control under investigation at JET:

- Gas fuelling
- Resonant magnetic perturbation (RMP)
- **Magnetic ELM pacing (plasma vertical kicks)**
- **ELM pacing by pellet injection**

Plasma vertical kicks at JET:

#77640 @ 59.29 s

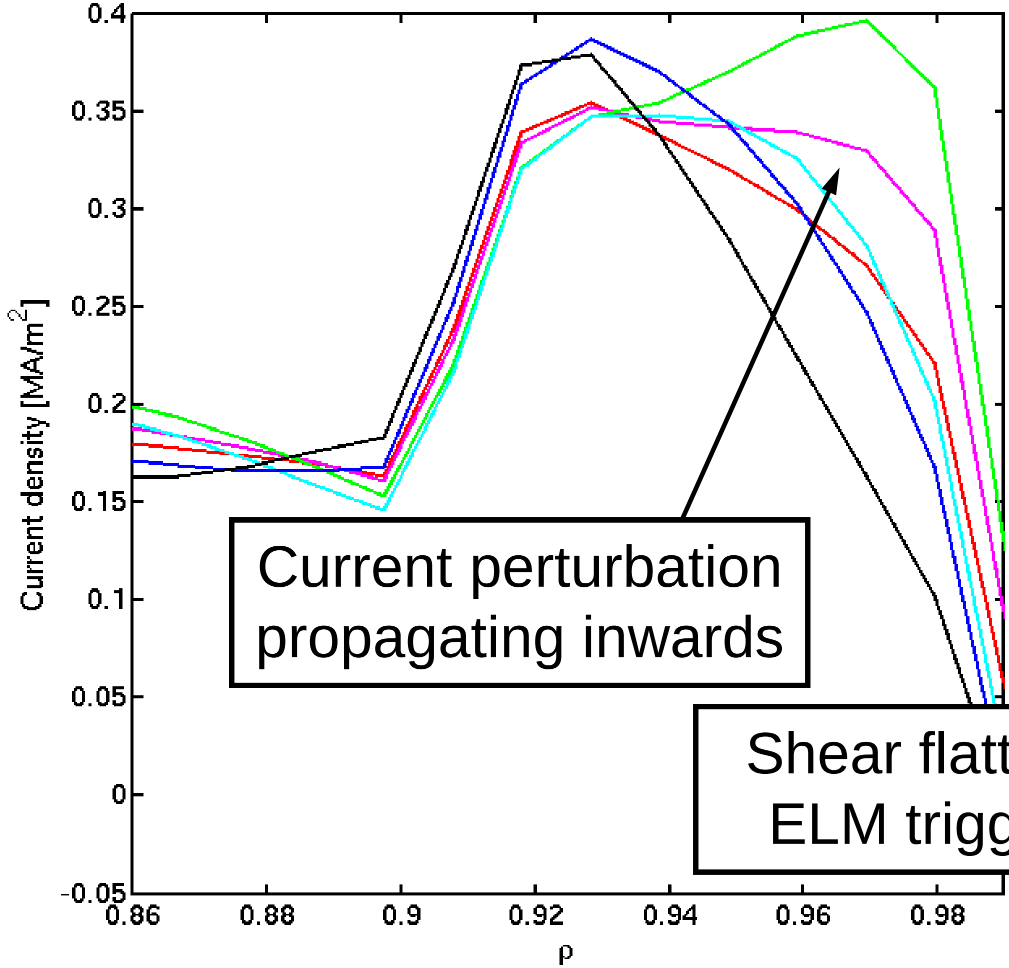


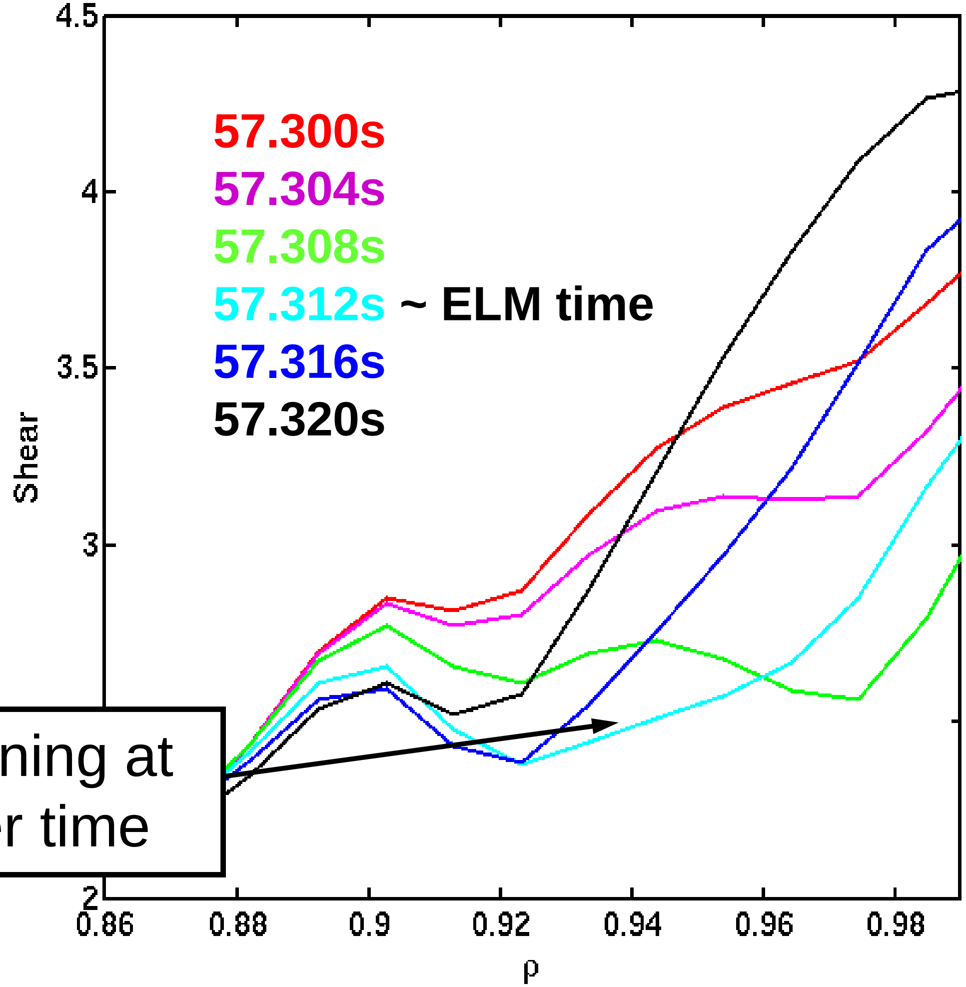
- **Sudden vertical plasma displacement by application of large voltages to the Vertical Stabilization circuit (max. $f_{kick} \approx 60$ Hz).**
- **Effects of kicks on the plasma:**
  - **Change in plasma shape / volume**
  - **Evolution of edge current profiles**
- **Plasma reaction to kicks:**
  - **Desired: ELM triggering for large enough kick perturbation**
  - **Side effect: Density reduction ("pump-out") at high f_{ELM}**

E. de la Luna, IAEA 2010

Kick cycle modelling:

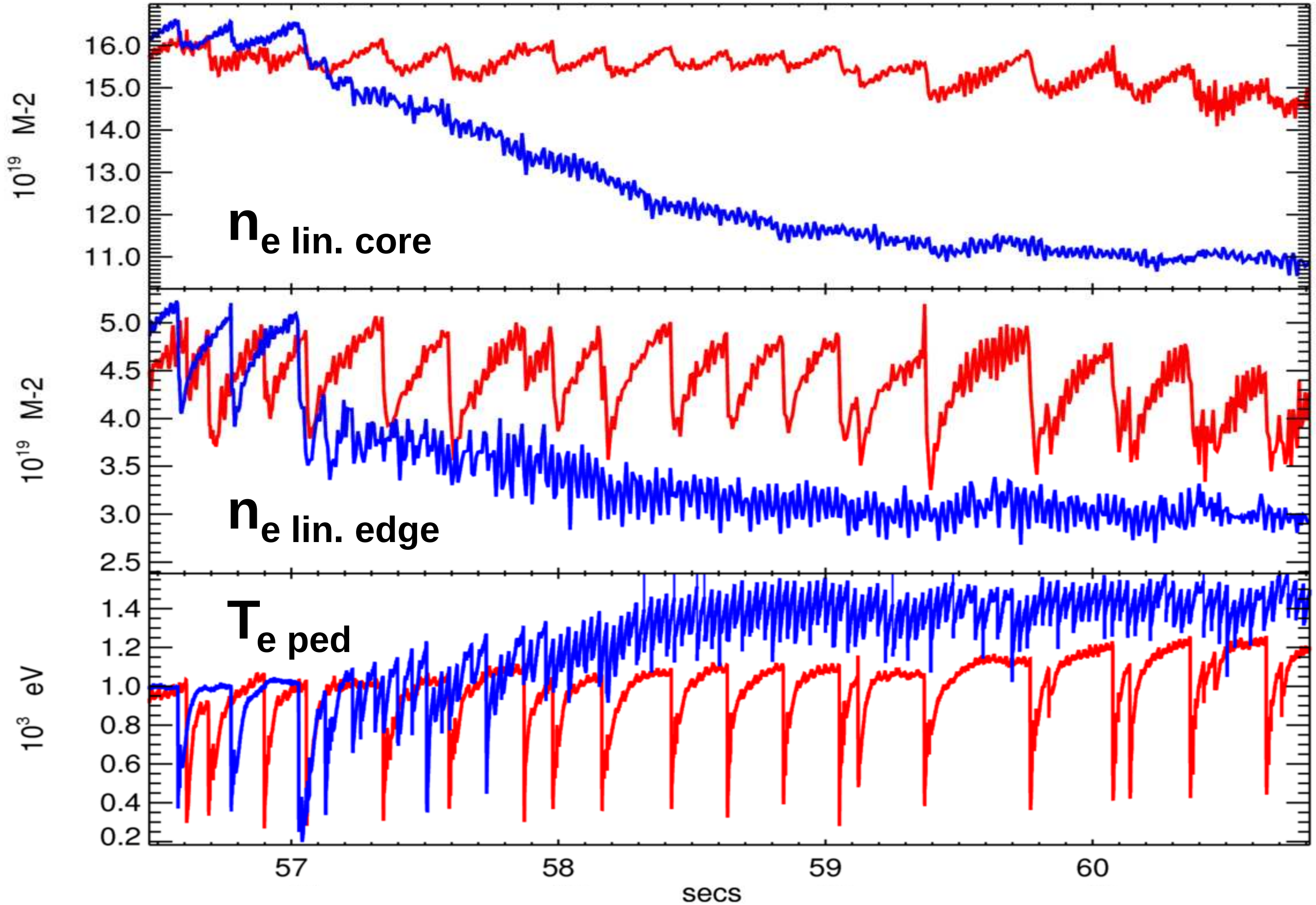
- **Simulation shows that pressure-driven instabilities are not triggered by kicks, but current driven instabilities are enhanced by low shear.**
- **We observe flattening of shear due to kicks:**





Density depletion with kicks:

Reduction in density at higher ELM frequency, with mild degradation in confinement:

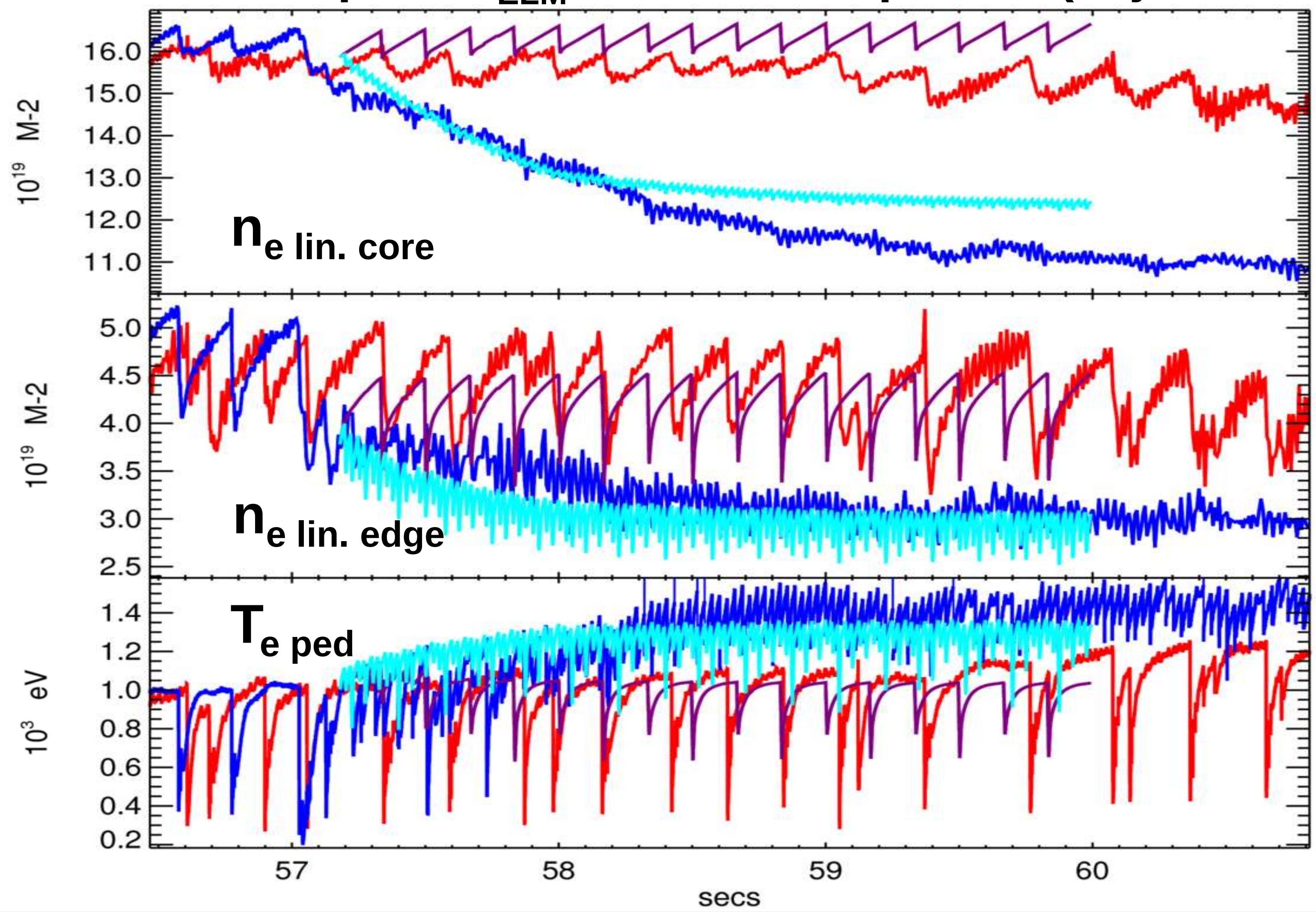


f_{ELM}≈6 Hz, experiment

f_{ELM}≈40 Hz, experiment

Density depletion with kicks:

Experimental trends can be reproduced with JINTRAC, same simulation conditions except for f_{ELM} and ELM amplitude (adjusted to ΔW_{ELM}):



f_{ELM}≈6 Hz, experiment

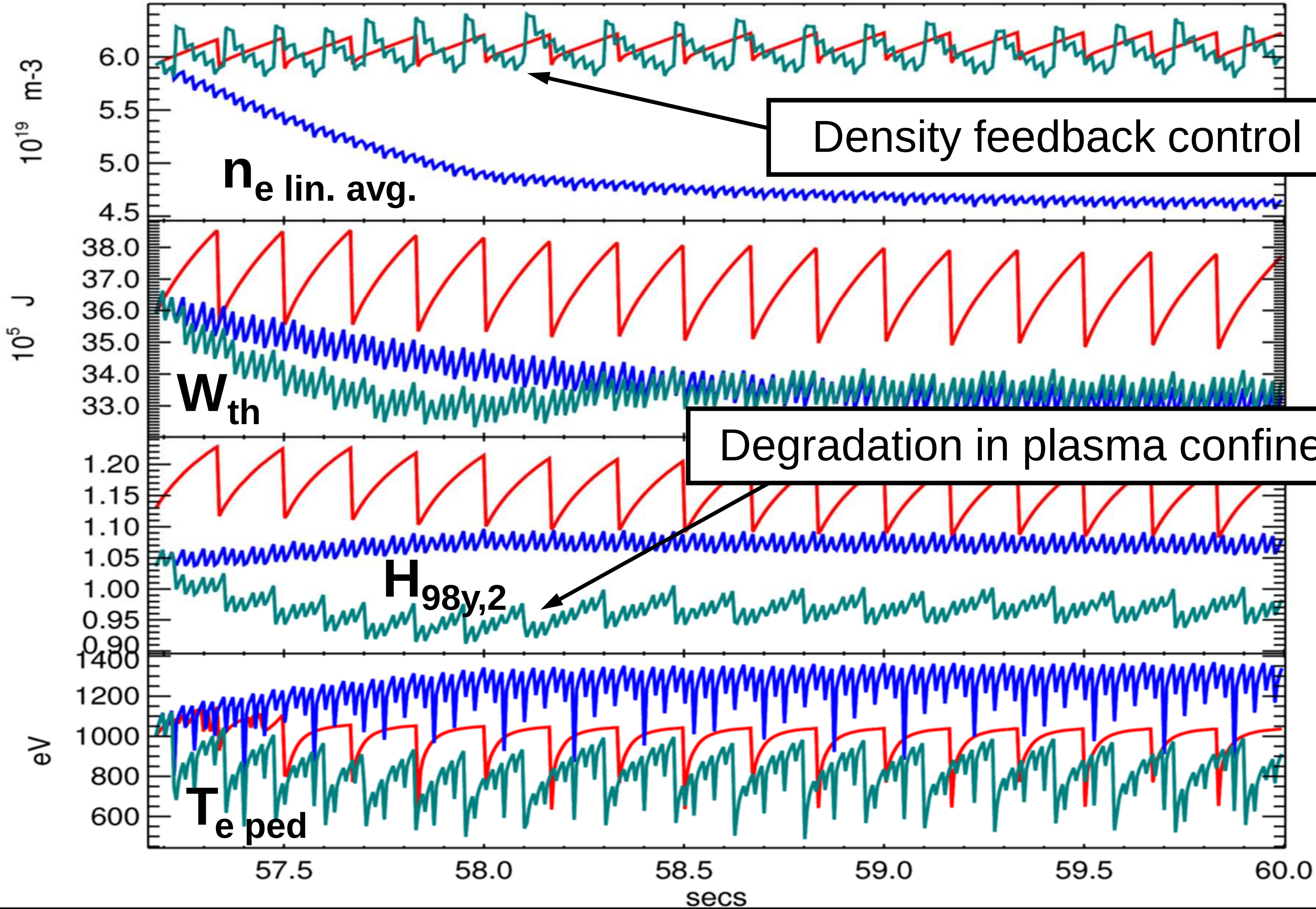
f_{ELM}≈6 Hz, simulation

f_{ELM}≈40 Hz, experiment

f_{ELM}≈40 Hz, simulation

Density depletion compensated by pellets in JET:

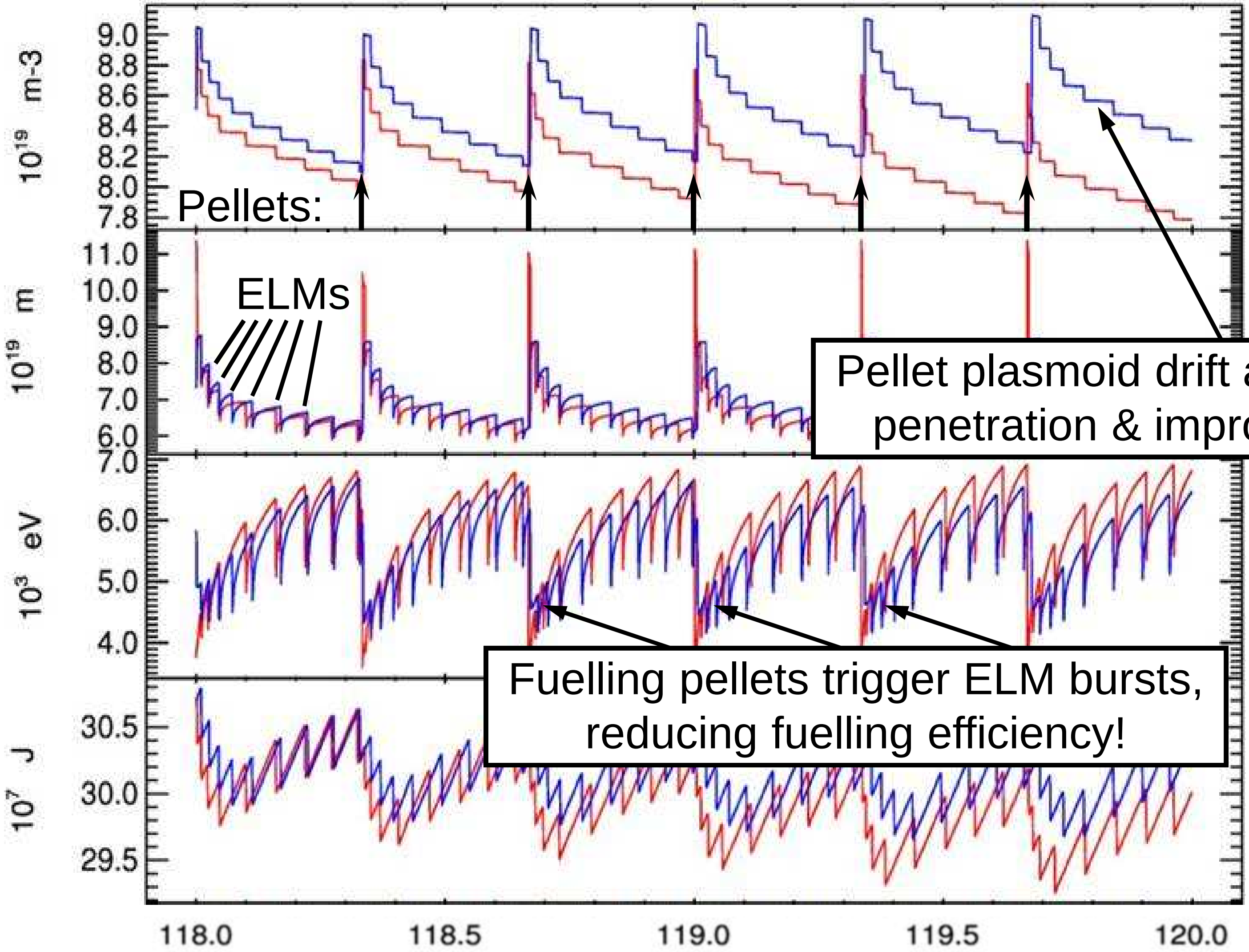
JINTRAC simulations, density maintained by pellet injection:



f_{ELM}≈6 Hz,
f_{ELM}≈40 Hz,
f_{ELM}≈40 Hz +pellets

Pellet fuelling ↔ ELM mitigation in ITER:

JINTRAC simulations of pellet fuelling in ITER ELM-mitigated regime:



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no plasmoid drift

with plasmoid drift

Summary:

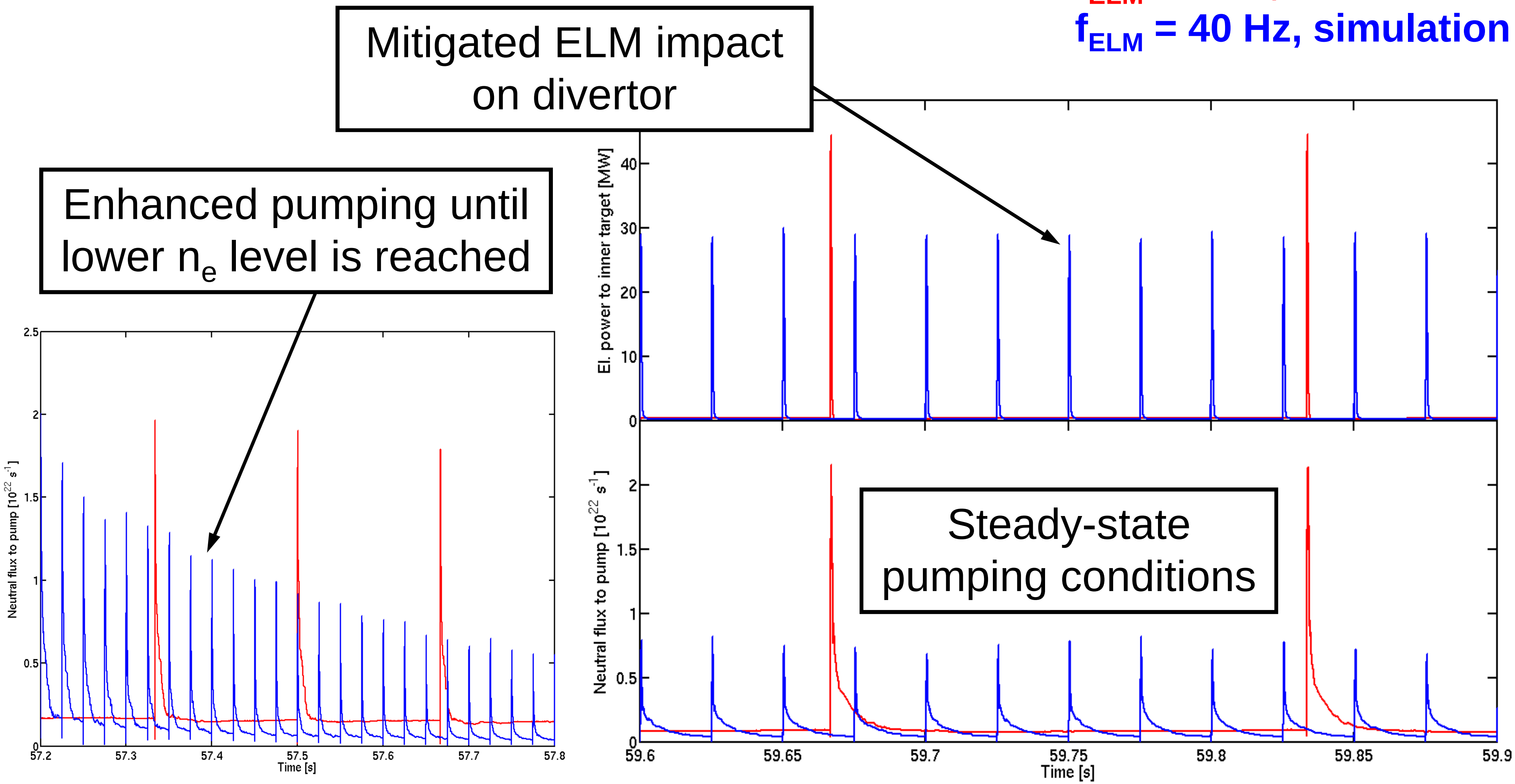
Summary:

- Kick-triggered ELMs can be reproduced assuming peeling mode (current driven) instabilities (pressure perturbation too small to reach critical gradient for natural ELMs).
- Shear modification due to combination of current reduction close to the edge + induced current close to top of pedestal may be responsible for ELM triggering and could explain ELM trigger time delay.
- Density depletion in mitigated regime appears to be natural consequence of different location of heat and particle sources and enhanced pumping efficiency; “mitigated” ELM mitigation due to change in SOL conditions.
- Pellet injection might help to recover initial density, but leads to a degradation in confinement.
- Fuelling efficiency of shallow pellet fuelling may decrease due to prompt pellet triggered ELMs and cause temporary variation of f_{ELM}.

Backup slides

Electron power to inner target / pumped neutrals:

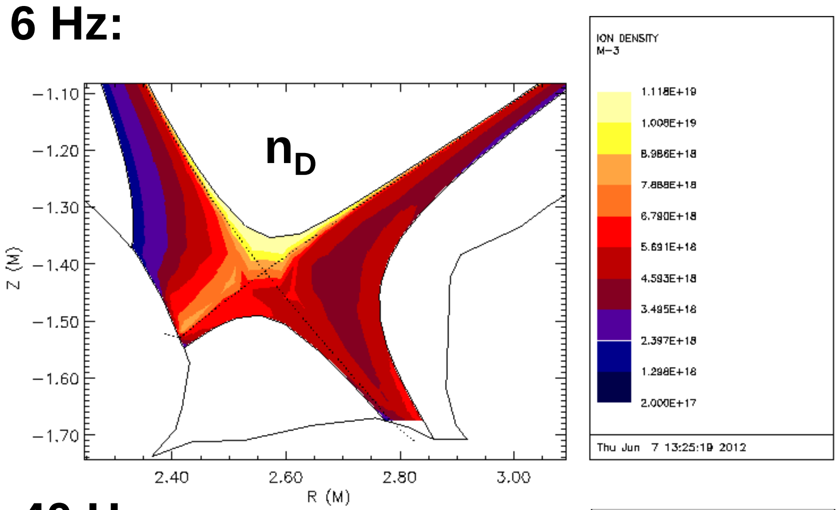
f_{ELM} = 6 Hz, simulation
f_{ELM} = 40 Hz, simulation

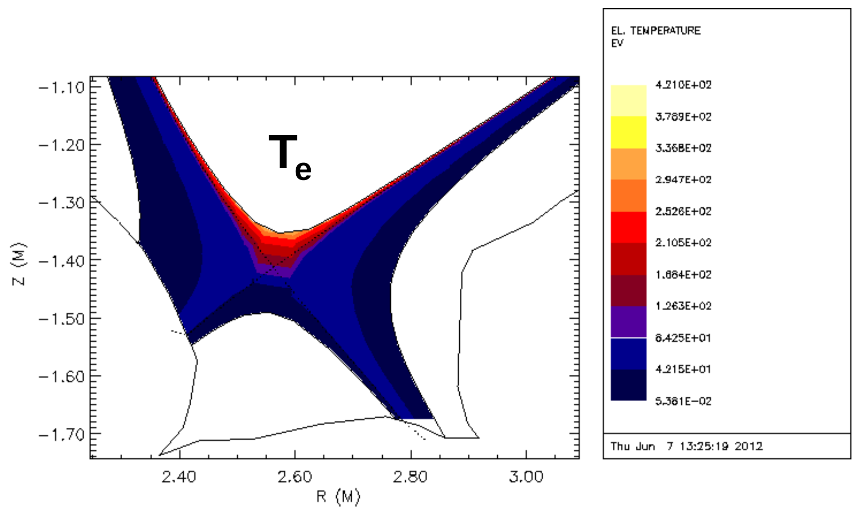


Effect of kicks on SOL:

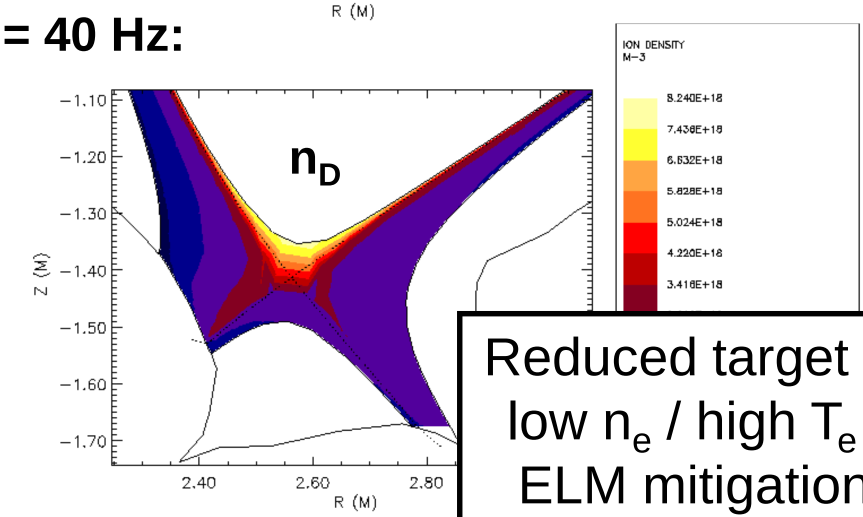
SOL contour plots (t ~ 60.0s):

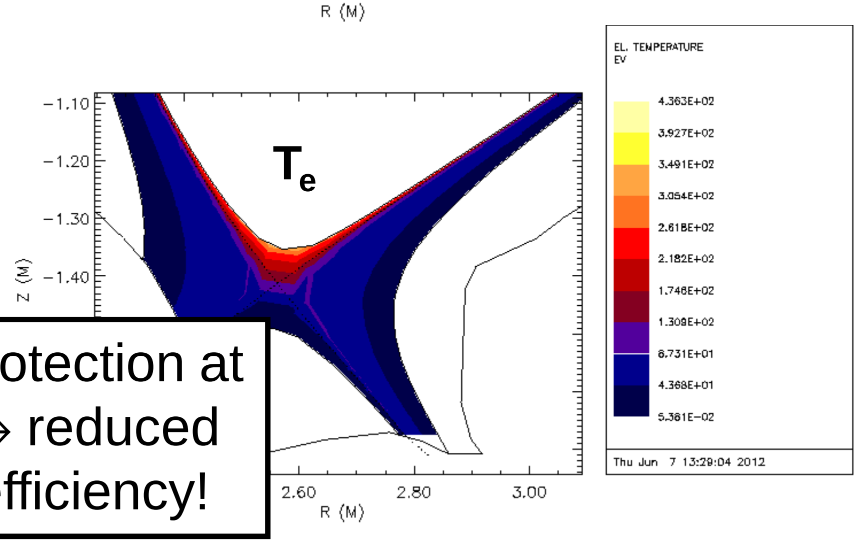
f_{ELM} = 6 Hz:





f_{ELM} = 40 Hz:





Reduced target protection at low n_e / high T_e → reduced ELM mitigation efficiency!